Better follow-up, increased awareness of the possibility of this complication, and more complete investigation will no doubt reveal a higher incidence.

Summary

There were 8,977 first insertions of the Lippes loop ; 3,168 were inserted before the patients went home and 5,809 at the postnatal visit.

The incidence of translocation was 8.7/1,000, about 15 times that reported by other investigators.

The low rate of translocation reported by others is due either to unawareness of this complication or to inadequate methods of diagnosis.

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Asbestos Bodies in Routine Necropsies on Tyneside: a Pathological and Social Study

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An association between inhalation of asbestos dust and the development of diffuse mesothelioma of pleura was first suggested by Wagner, Sleggs, and Marchand (1960) in South Africa. Further studies in South Africa, Britain, and elsewhere have provided confirmatory evidence and have also shown that the peritoneum may react in a similar way (Thomson, 1962 ; Hourihane, 1964 ; Enticknap and Smither, 1964 ; Owen, 1964 ; Elmes, McCaughey, and Wade, 1965 ; Selikoff, Churg, and Hammond, 1965). In many cases evidence of only brief exposure to asbestos has been found. In a series of cases of mesothelioma Thomson (1962) found evidence of limited asbestosis in the lung bases of many subjects with no known history of occupational exposure to asbestos and went on to investigate the incidence of asbestos bodies in lung smears at routine necropsies in Cape Town, finding bodies in over 25% of cases. Subsequent studies of lung smears in other cities have shown an incidence ranging from 27 to 47% of cases (Thomson and Graves, 1966 ; Cauna, Totten, and Gross, 1965 ; Anjilvel and Thurlbeck, 1966 ; Roberts, 1967). Asbestos bodies have also been found in histological sections of lung tissue from routine necropsies, with an incidence ranging from 6% (Hourihane, 1964) to 58% (Meurman, 1966).

The present analysis of the frequency of asbestos bodies in the lung at routine necropsy was undertaken in association with a survey of cases of mesothelioma in the major shipbuilding area of Tyneside. The objects of the study were to ascertain the incidence of asbestos exposure in the population served by the Royal Victoria Infirmary in Newcastle upon Tyne ; to trace, if possible, the source of any asbestos found ; and to use the results as a control with which to compare the incidence of asbestos bodies in cases of diffuse mesothelioma of pleura and peritoneum diagnosed in the Royal Victoria Infirmary and in neighbouring hospitals in Tyneside and Wearside. The mesothelioma series will be described in detail in a further communication.

The largest consumer of asbestos in the area is the shipbuilding industry, where it is used mainly as an insulator for boilers, pipes, bulkheads, etc. Asbestos is, however, used in other local industries in the manufacture of products such as floor tiles, brake linings, and mattresses.

Materials and Methods

Smears were prepared from the lungs of 311 patients aged 15 years or over coming to necropsy in the department of pathology, University of Newcastle upon Tyne. An incision approximately 1 cm. in depth was made in the base of the right lung, the cut surfaces were scraped with a knife, and the exuding fluid was smeared on a standard microscope slide. The smears were allowed to dry, fixed in alcohol, and mounted unstained in DPX under a 20 by 50 mm. coverslip, the area beneath the coverslip being systematically examined. To be accepted as asbestos bodies the following criteria were required: refractility, a pale central fibre, smooth or segmented yellowish encrustation, and clubbed or rounded ends. Many smears contained the "curious bodies" described by Tylecote and Dunn (1931) and by Williams (1934), but these consisted of a black central fibre or spicule encrusted with pale yellow refractile material and were easily distinguished from asbestos bodies. In a few cases smears containing asbestos bodies were stained by the Prussian blue method, when they gave a positive reaction. In a number of smears asbestos bodies were too numerous to be counted direct, and an estimate of the number present was made by taking the mean count in 10 fields taken at random

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and applying this to the area under the coverslip. One smear was examined from each of the 311 cases.

At the same time as the smear was made, a block of lung tissue was usually taken from the adjacent lung and fixed in formol-saline for histological examination. Where the smears contained asbestos bodies, 6-μ paraffin sections were prepared and stained either with haematoxylin and eosin or with a light green counterstain which rendered asbestos bodies more easily visible, though they did not take up the dye. Sections were again systematically examined for asbestos bodies.

When asbestos bodies were found an attempt was made to trace the source of the asbestos by means of a simple questionary sent to the patient's next of kin. If no reply was received the relatives were interviewed in person.

Results

Smears

Asbestos bodies were found in 20.3% of smears from 311 necropsies. Bodies were commoner in males (25.5% of 196 cases) than in females (11.3% of 115 cases). In Table I the cases are divided into 10-year age groups. No positive smears were found in males below the age of 25 or in females below the age of 35, but the number of cases in these age groups is small. Among males between 35 and 84 years the incidence of positive smears rises to a peak in the 65–74 age group and falls off sharply thereafter. Female cases show more fluctuation in the early age groups with no distinct peak in later life.

Since the smears must have varied slightly in thickness, it is not permissible to make strict comparisons of the number of asbestos bodies from case to case. However, it was possible to divide cases into those with small numbers (1 to 34 per smear) and those with large numbers (171 to 3,363 per smear) (Table II). In the latter group were 15 males and two females. There was no apparent relation between age and the number of bodies in the smear.

TABLE I.—*Proportion of Cases Giving Positive Smears, Arranged in 10-Year Age Groups*

Age	Males			Females			Males + Females		
	All Smears	Positive Smears		All Smears	Positive Smears		All Smears	Positive Smears	
		No.	%		No.	%		No.	%
15–24	2	0	0	3	0	0	5	0	0
25–34	4	1	25·0	0	0	0	4	1	25·0
35–44	17	2	11·8	9	3	33·3	26	5	19·2
45–54	31	9	29·0	21	0	0	52	9	17·3
55–64	56	12	21·4	25	3	12·0	81	15	18·5
65–74	53	21	39·6	30	3	10·0	83	24	28·9
75–84	29	3	10·4	26	4	15·4	55	7	12·7
85–94	4	2	50·0	1	0	0	5	2	40·0
Total	196	50	25·5	115	13	11·3	311	63	20·3

TABLE II.—*Relative Numbers of Asbestos Bodies in Smears*

No. of Asbestos Bodies per Smear	No. of Cases
1–34	46
35–170	0
171–3,363	17

Histological Sections

Histological sections of lung tissue were available in 62 of the 63 cases with positive smears. In 56 cases sections were taken from the tissues adjacent to the incision from which the smear was made; in six cases they were taken at random.

Asbestos bodies could not be identified in just over half (53%) of the sections examined (Table III), all coming from cases with small numbers of bodies in the smear. Rather more than a third of the sections contained a few scattered asbestos bodies which could easily have been overlooked on examining the section in the normal manner. The bodies usually occurred singly, though occasionally in groups of two or three, generally within an air space, and the greatest number found in a single section in this group was 12. The remaining sections (about one-ninth of the total) contained larger numbers of bodies, usually disposed within air spaces in various-sized aggregates which were often separated by several millimetres of lung tissue.

TABLE III.—*Comparison of Numbers of Bodies in Smears and Sections*

Smears		Sections		
No. of Bodies per Case	No. of Cases	No. of Cases With		
		No Bodies	Scanty Bodies	Numerous Bodies
Scanty	45	33	12	0
Numerous	17	0	10	7
Total	62	33	22	7

Histological evidence of early asbestosis, in the form of mild fibrosis with asbestos bodies situated in the interstitial tissues, was found in 10 cases, including all seven with numerous bodies in the sections and three with 12 bodies or fewer. When present, asbestosis was not confined to the subpleural tissues but appeared also in deeper areas of the lung. Usually the asbestosis was very slight in extent, interstitially situated bodies being widely scattered. The histological picture was often complicated by the presence of much carbonaceous dust, sometimes with focal emphysema (Heppleston, 1953), and of active chronic non-specific interstitial inflammation. There were no cases of classical asbestosis. All the sections showing asbestosis came from cases with numerous bodies in the smears. Lung smears thus appear to be a more reliable means of detecting scanty asbestos bodies than 6-μ histological sections.

Diagnosis

Asbestos exposure has been shown to cause lung carcinoma (Doll, 1955) and has been associated with diffuse mesothelioma of pleura and peritoneum (Wagner *et al.*, 1960; Hourihane, 1964). It has also been associated with an increased incidence of carcinoma of stomach, colon, and rectum (Selikoff, Churg, and Hammond, 1964). The present series (Table IV) includes 11 cases of lung carcinoma, three of which gave a positive smear for asbestos bodies, and one case of mesothelioma of pleura which was also positive. There were 22 cases of carcinoma of stomach, colon, or rectum, seven of which gave positive smears. All other cases in which malignant disease was diagnosed (carcinomata of various organs, leukaemias and reticuloses, a cerebral glioma, and an argentaffinoma of ileum) were combined, and a final category comprises patients dying from miscellaneous non-malignant diseases, including benign tumours. The various malignant groups taken either separately or together show a higher incidence of positive smears than the non-malignant group, but the difference is not statistically significant ($\chi^2=2.23$, $P=0.13$ for all malignant diseases combined).

TABLE IV.—*Proportion of Positive Smears Grouped by Diagnosis*

Diagnosis	Positive Smears	All Cases	% Positive
Mesothelioma of pleura	1	1	
Lung carcinoma	3	11	27·3
Carcinoma of stomach, colon or rectum	7	22	31·8
All other malignant diseases	9	40	22·5
All malignant diseases	20	74	27·0
Miscellaneous non-malignant diseases	43	237	18·1

Geographical Incidence

The cases were divided into four categories according to the situation of their home addresses (Table V). The first category consists of patients residing in Newcastle City, its immediate northern suburbs, and the other urban areas bordering both sides of the lower reaches of the river Tyne. This category also includes patients living in the town of Blyth, where shipbuilding has been carried on until recently. These districts include all the shipbuilding, ship-repairing, and ship-breaking yards on Tyneside, the docks, and a large proportion of other local industries. The second category consists of patients living in Northumberland, the majority of these coming from mining villages and small country towns. The third category consists

TABLE V.—*Geographical Incidence of Positive Smears*

	All Cases	Positive Cases
Urban areas	227	58 (25·6%)
Northumberland County	57	2 (3·5%)
County Durham	19	2 (10·5%)
Distant areas	8	1 (12·5%)

TABLE VI.—*Source of Asbestos Fibres in Cases with Positive Smears*

Case No.	Sex	Age	No. of Asbestos Bodies in Smear	Occupation or Source of Asbestos
				Group 1
1	M	62	21	Ship's painter—used asbestos cloth insulation in ships
2	M	57	855	Shipyard pipe-lagger
3	F	57	855	Sweeping up for pipe-laggers in shipyard
4	M	65	570	Labouring in ships to boilermakers
5	M	49	1,767	Caulker in shipyard
6	M	65	912	Dock labourer—handled asbestos
7	M	44	2	Builder's lorry driver. Delivered asbestos materials at times
8	M	47	228	Lorry driver's mate. Sometimes handled asbestos-covered boilers
9	M	69	15	Jobbing builder—occasionally used asbestos
10	M	68	6	Wore asbestos protective clothing in a steel works
11	F	72	6	Wife of pipe-lagger. He also used asbestos at home
12	F	42	2	Lived in asbestos "prefab." for 13 years
				Group 2
13	M	34	2	Ship's engineer. Probably repaired broken lagging
14	M	56	19	Shipyard red leading. Probably near others using asbestos
15	F	84	1	Shipyard joiner's labourer. Probably contacted asbestos in ships
16	M	51	428	Shipyard labourer. Probably contacted asbestos in ships
17	M	49	10	Shipyard plater and rivetter—also fitted boilers in ships
18	M	53	34	Shipyard caulker
19	M	51	3	Shipyard french polisher. Probably worked with asbestos very occasionally
20	M	60	741	Shipyard rigger, fitting propellers, boilers, etc.
				Group 3
21	M	75	3	Worked in shipyards about 30 years before death
22	M	72	912	Driller in shipyard most of his life
23	M	64	24	Builder's labourer. Shipyards in early life for 8 weeks
24	M	66	855	Shipyard electrician 23 years
25	M	69	1	Hand riveter and crane driver in shipyards
26	M	72	513	Shipyard blacksmith's striker over 20 years
27	M	67	2	Shipyard storeman all his life
28	M	68	29	Grinder 2 years. Painter in shipyards 3–4 years
29	M	63	2,565	Metal driller in shipyards and engine rooms most of his life
30	M	66	24	Shipwright 10 years
31	M	59	1	Plater in ship repair yard 17 years
				Group 4
32	M	69	1	Policeman. Point duty 14 years
33	M	55	1	Builder's labourer
34	M	62	4	Builder's labourer
35	M	71	1	Coal miner 10 years. Builder's labourer
36	M	52	15	Driller in boiler shop
				Group 5
37	M	72	7	Ship's butcher 30 years
38	M	78	1	Office clerk 40 years
39	F	55	1,083	Pastry cook for a total of 15 years
40	M	70	171	Coal miner for 52 years
41	M	66	4	Joiner, railway waggon repair shops
42	M	61	1	Several jobs—including civil service
43	M	43	25	Metal worker in turbine works
44	M	70	1	Coal miner 6 years, then labourer in factory machine shop
45	M	69	1	Draughtsman
46	M	68	18	Machinist
47	F	55	4	Housewife. Shop assistant in music shop
48	M	68	2	Cafe proprietor—previously tailor
49	F	37	6	Laundry worker—wool winder
50	F	67	2	Housewife. Domestic servant
51	M	58	19	Colliery electrician. Subsequently G.P.O. engineer
52	M	86	1	Blacksmith
53	F	77	1	Housewife. Tailoress
54	M	54	2	Coal miner—regular soldier—chauffeur and coach driver

of patients who lived in County Durham, again mostly in small towns and villages, while a small number of subjects from places outside the Tyneside area altogether comprise the final category.

Table V shows that the incidence of positive smears in subjects from urban areas is much higher than that in subjects from rural Northumberland. The incidence in County Durham is greater than that in Northumberland, though still smaller than the urban incidence, but the number of cases in this category is smaller and the significance of this result is uncertain. The Northumberland cases with positive smears are Cases 12 and 23 (Table VI) and those from County Durham are Cases 10 and 48.

Source of Asbestos

The occupational questionary relating to cases with positive smears was returned in 36 instances and in a further 18 the next of kin were interviewed. No information is available about nine cases, either because they had no surviving relatives or because relatives could not be contacted. Information was available in 14 of the 17 cases with numerous asbestos bodies in their smears. The replies to the questionaries were usually brief, and both in questionaries and in interviews many relatives knew few details of the patient's work. The occupational information is therefore scanty, and in patients who held many jobs often refers only to the later part of their lives. Only one patient was stated to have used asbestos at home in his spare time, and he was also exposed at work. None was stated to have lived near an asbestos factory.

On the basis of this information the cases have been divided into five groups. Group 1 consists of 12 patients in whom there was a definite history of contact with asbestos-containing materials, and in 10 of these the exposure occurred at work. Five were shipyard workers who actually applied asbestos insulation or worked in close association with those who did so, one was a dock labourer who from time to time handled cargoes that included raw and manufactured asbestos, two were lorry drivers whose loads at times included asbestos, one was a builder who occasionally used asbestos materials, and one was a steel worker who handled asbestos-covered hoses and wore asbestos clothing while cooling molten slag. Of those not exposed at work, one was the wife of a shipyard pipe-lagger, whose husband's clothes were covered with asbestos dust after work, while the other, also a woman, lived for 13 years in a prefabricated house made of asbestos.

Group 2 contains eight cases in which relatives thought there had probably been contact with asbestos. One individual was a ship's engineer who probably had to repair damaged asbestos insulation, and the others were all shipyard workers who probably were exposed to dust from asbestos insulation.

The remaining 34 cases had no known history of such contact. However, groups 1 and 2 together include a high proportion of shipyard workers, and the 11 patients among the remaining 34 who had ever worked in a shipyard were therefore placed together as group 3. Most of these had been employed in shipyards for many years, though in one instance (24 bodies in the smear) for only two months. Twelve of the 14 patients whose smears contained numerous asbestos bodies are included in groups 1, 2, and 3, and 10 of these were shipyard workers.

The man with mesothelioma (Case 31) is included in group 3. He served a five-year apprenticeship as a plater in a ship-repair yard and for a further 12 years worked intermittently as a plater's helper. This period included the years of the industrial depression, when he was often unemployed or took other jobs. Then for 26 years he worked as a caretaker in a furniture storage warehouse, apart from four years during the war when he was a stoker in coal-fired trawlers, before dying from mesothelioma. In the warehouse he usually handled furniture and once china clay, but there was no history of asbestos contact.

Five further patients had had occupations suggesting possible contact with asbestos and constitute group 4. Three were builder's labourers who may have handled asbestos-containing materials. The fourth served 21 years in the police force and then worked as a postman; for 14 years of his police service he was engaged on point duty and may possibly have inhaled asbestos fibres derived from brake linings, etc. The fifth patient worked for some years as a driller in a boiler shop and possibly had contact with asbestos insulation.

Group 5 consists of the remaining 18 patients with no known contact who, with two exceptions, all had smears containing small numbers of asbestos bodies. One woman (1,083 bodies) had been a housewife for most of her life, but had worked as a pastrycook for 15 years; while a man (171 bodies) had been a coal miner for over 50 years. The others had a variety of occupations, apparently unconnected with asbestos (Table VI).

The possibility of exposure to asbestos through living in the neighbourhood of an asbestos factory has been considered in groups 4 and 5. The most likely sources of neighbourhood contamination by asbestos dust are the shipyards, the docks where raw asbestos is unloaded, and several factories where asbestos-containing products are made. Only one of the 23 patients in groups 4 and 5 lived less than half a mile (800 m.) from the river or the nearest asbestos factory, and asbestos from these sources is probably not important in this series.

Discussion

The incidence of asbestos bodies in histological sections of lung from routine necropsies has varied widely. Hourihane (1964) found bodies in none of 50 consecutive necropsies in patients without intrathoracic tumours and in 6% of 50 necropsies in patients with lung carcinoma, while Meurman (1966) found them in 57.6% of cases, using 20-μ sections. Elmes *et al.* (1965) found bodies in 14 and 27% respectively of two different age groups (again excluding cancers of lung and pleura).

The incidence of positive smears in the present series of cases is rather lower than that found by Thomson, Kaschula, and MacDonald (1963) in Cape Town (26.4%), by Thomson and Graves (1966) in Miami (27.2%), and by Roberts (1967) in Glasgow (28%), and much lower than that found by Cauna *et al.* (1965) in Pittsburg (41%) or by Anjilvel and Thurlbeck (1966) in Montreal (48%). The latter authors, however, by comparing different methods of making smears, have shown that the technique used may greatly influence the apparent incidence of asbestos bodies. In one method the lung was bisected, the cut surface was scraped with a slide, and two to four smears were made from the fluid collected from each lobe (presumably four to eight smears per lung): 48% of cases were found to contain asbestos bodies. In the second method fluid was squeezed on to a slide from an incision in the base of the lung and a single smear prepared: only 21% of positive cases were found. This figure is very close to that obtained in the present series by a similar technique (20.3%), and it is possible that had more lung tissue been sampled and a larger number of smears prepared in each case, the incidence of positive cases in Newcastle would have been higher. Cauna *et al.* (1965) also used an incision-and-squeezing technique, but they prepared four smears in each case from various parts of the lung.

The present series confirms the earlier findings of a higher incidence of positive smears in male subjects than in females. Indeed, Roberts (1967) was unable to find any asbestos bodies in his 38 female subjects. Again as in previous studies the majority of smears in the present series contained scanty asbestos bodies while in only 17 smears were bodies numerous, only two of the latter coming from females.

The higher incidence of positive smears and smears with numerous bodies in males suggests that inhalation of asbestos dust tends to occur at work rather than in the residential environment. Table VI shows that more than a third of the cases with positive smears and more than half of those with numerous bodies in the smear worked in shipyards at some time, often for many years. The majority were tradesmen who definitely or probably worked inside ships. The shipyard workers with scanty asbestos bodies in the smears mostly spent a relatively short period in the yards or had jobs outside the ships.

Though now increasingly being replaced by other materials, asbestos and asbestos-containing mixtures have been used for many years for thermal insulation and fireproofing in ships. All boilers and steam pipes are lagged with these materials, and the inner surfaces of the hull and surfaces of decks and bulkheads are sometimes coated with a layer of asbestos several inches in thickness. The asbestos is applied by a variety of methods, most of which produce much dust. During the "fitting out" of a ship—that is, while engines, boilers, pipework, auxiliary machinery, electrical wiring, etc., are being installed—men of a wide variety of trades work within the ship at the same time, often close together and in confined spaces with poor ventilation. Thus not only are the insulation workers exposed to dust from the asbestos materials but also other tradesmen, such as electricians, welders, drillers, painters, etc., and their assistants. Apart from the shipyard workers, a number of subjects had a history of handling asbestos incidentally in the course of their work or had occupations where there was a possibility of exposure.

There was no instance of classical severe asbestosis in this series of cases from which post-mortem lung smears were made. Histological evidence of minimal asbestosis was found in 10 cases, but this was of no clinical significance, and the patients all died from other causes. There was no significant excess of positive smears among those dying from bronchial or gastrointestinal carcinoma. The main significance of the present findings lies in the association between asbestos exposure and diffuse mesothelioma.

A detailed analysis of the cases of mesothelioma will be the subject of a further communication (Ashcroft, 1968), but it is relevant to mention one aspect here. Lung tissue was available for histological examination in 23 cases of diffuse mesothelioma of pleura or peritoneum coming to necropsy on Tyneside. Asbestos bodies were found in the sections from 21 cases (91%). One of these cases is included in the smear series but no smears were made in the remainder. When the cases of mesothelioma are compared with the smear series the greater incidence of asbestos bodies in the mesothelioma cases is highly significant ($\chi^2=54.4$, 1 D. of F., $P<0.001$). However, when the number of bodies in individual cases of mesothelioma is considered there is no tendency for the histological sections of these cases to show more bodies than those of the control cases, and indeed a majority (15 out of 21) of the mesothelioma cases show only scanty asbestos bodies in lung sections. The 95% confidence limits for the proportion of mesothelioma cases showing asbestos bodies (21 out of 23 in this series) suggest that at least 72% of all mesothelioma cases will have asbestos bodies in the lung. Though it is legitimate to compare this figure only with a series using the same technique, it is worth pointing out that even the most refined method of making smears (Anjilvel and Thurlbeck, 1966) yields an upper estimate of 48% in a general population. The present results thus support an association between mesothelioma and the presence but not the number of asbestos bodies in the lung.

Summary

Smears were prepared from the base of the right lung in 311 routine necropsies of patients over 15 years of age. Asbestos bodies were found in 20.3% of cases (25.5% of 196 males and 11.3% of 115 females). The majority of smears contained scanty bodies, but in 17 cases they were numerous. In cases

with positive smears histological sections failed to reveal asbestos bodies in over 50%. Histological evidence of minimal asbestosis was found in 10 cases. There were no cases of classical asbestosis. The series includes one case of mesothelioma of pleura. There was no significant excess of positive smears in patients dying from gastrointestinal or lung carcinoma. The incidence was higher in patients living in urban areas (25.6%) than in those from rural areas (3.5%). Twenty-nine patients definitely or probably were exposed to asbestos dust at work and two further patients had non-occupational exposure. Neighbourhood contamination with asbestos dust is probably not important in this series. When compared with a series of 23 cases of mesothelioma of pleura or peritoneum, 21 (91%) of which showed asbestos bodies in histological sections of lung, the greater incidence of asbestos bodies in the cases of mesothelioma is statistically highly significant.

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Method for Estimating Objectively the Comparative Merits of Biological Tests of Lead Exposure

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Many biological tests are used for the diagnosis of lead-poisoning and for the control of lead absorption in industry. The punctate basophil count and haemoglobin (Legge and Goadby, 1912), urinary lead (Belknap, 1935), blood lead (American Public Health Association, 1943), urinary coproporphyrin (de Langen and Ten Berg, 1948), and urinary δ-aminolaevulinic acid (ALA) (Haeger-Aronsen, 1960) have been recommended, and are still used (Zielhuis, 1961; Ministry of Labour, 1964; Moncrieff *et al.*, 1964; Dagg *et al.*, 1965; Cramér and Selander, 1965; Williams, 1966).

The comparative merits of these tests of lead exposure have been estimated objectively by an original statistical method, with use of data obtained from a survey of lead workers.

The Survey

The survey was made in a lead-acid battery factory. Personal samplers (Casella & Co., 1966; Williams, 1967) were worn on the coat lapel by a number of workers every shift for two weeks to obtain accurate estimates of the lead-in-atmosphere concentration to which they were exposed. During the second week blood lead, urinary lead, urinary coproporphyrin, urinary ALA, the punctate basophil count, and haemoglobin were estimated daily. Lead workers were sought whose exposure to lead was as constant as possible and had continued long enough for the biological variables to be fairly stable. The selection criteria adopted were that there had been no change of job within the last year; no recent sickness, holiday, or other absence; and no change in overtime or in productivity for six months. The jobs of men selected represented the full range of lead exposure available, and did not entail wearing respirators. Of the men in the factory who fulfilled these criteria the following 40 were chosen: all the six machine pasters (M), all the eight hand pasters (H), all the six hand casters (C), the first 10 to volunteer of the 15 forming men (F), and the first 10 to volunteer of 18 controls (O) from departments making plastics. The element of self-selection in the forming men and controls was thought to be unimportant because the men knew there was no likelihood of their job or their wages being affected, or an illness discovered, as a result of entering the survey.

The men were studied in four groups of 10. Each man wore one of ten personal samplers for the whole of each shift, from clocking in to clocking out. Different samplers were worn daily, in a randomized sequence. In the second week daily samples for blood lead by venepuncture, urinary lead, punctate basophil count, and haemoglobin were collected between 10 and 11 a.m. Another urinary sample for coproporpyhrin and ALA was collected between 12 noon and 1 p.m.

Blood lead and urinary lead samples were analysed by a modification of the method of King and Thompson (1961), and lead-in-air samples were estimated polarographically by one of us (E. K.). Urinary coproporphyrin was estimated by the semiquantitative method of Donath (1956), and urinary ALA by a simplification (Williams and Few, 1967) of the method of Mauzerall and Granick (1956), by one of us (M. K. W.). Punctate basophil counts were made by an experienced technician using Lane's (1949) method, and haemoglobin estimations were undertaken by an experienced State-registered nurse using the M.R.C. grey wedge photometer. The collection of samples and the analytical methods, together with the men's jobs, have been described in detail elsewhere (Williams, 1967).

The cost of each test was estimated as follows. The time off work of each man and the time of the medical staff to collect

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